AD-A061 331 NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA F/G 14/5
BLOOMING IN A CHARGE-COUPLED DEVICE IMAGER. BLOOMING CONTROL RE--ETC(U)
SEP 78 P S CATANO

UNCLASSIFIED NOSC/TR-298 NL

1 OF 1
AD
A061331

END
DATE
FILMED
1 -79
DDC

NOSC

NOSC TR 298

NOSC TR 298

Technical Report 298

6

BLOOMING IN A CHARGE-COUPLED DEVICE IMAGER

Blooming control recommendations are given for low-light-level CCD imagers with time delay and integration, such as the LOPATCH sensor

10 P S Catano

11 15 September 1978

12 26p.

9 Final Report: January - June 1978

Prepared for
Naval Electronic Systems Command (ELEX 0304)
Washington DC 20360

14 NOSC/TR-298

17 XF12151004

16 F12151

Approved for public release; distribution unlimited.

NAVAL OCEAN SYSTEMS CENTER
SAN DIEGO, CALIFORNIA 92152

NAVAL OCEAN SYSTEMS CENTER, SAN DIEGO, CA 92152

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

RR GAVAZZI, CAPT USN
Commander

HL BLOOD
Technical Director

ADMINISTRATIVE INFORMATION

The work covered in this report was performed by members of the Electro-optics Sensors Branch (NOSC Code 7313) under Program Element 62712N, Project F12151, Task Area XF12151004 for the Naval Electronic Systems Command. The report covers work performed from January to June 1978 and was approved for publication 15 September 1978.

The author is grateful to LB Stotts and SE Moran of NOSC for their technical assistance in the program. The author also wishes to thank SB Campana of Naval Air Development Center, Johnsville, for his assistance and support of the work.

Released by
FM Tirpak, Head
Sensor Technology Division

Under Authority of
RE Shutters, Head
Surface/Aerospace Surveillance
Department

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NOSC Technical Report 298 (TR 298)	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) BLOOMING IN A CHARGE-COUPLED DEVICE IMAGER Blooming control recommendations are given for low-light-level CCD imagers with time delay and integration, such as the LOPATCH sensor		5. TYPE OF REPORT & PERIOD COVERED Final January–June 1978
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) PS CATANO		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Ocean Systems Center San Diego, California 92152		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62712N, F12151 XF12151004 (NOSC SS12)
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Electronic Systems Command (ELEX 0304) Washington, DC 20360		12. REPORT DATE 15 September 1978
		13. NUMBER OF PAGES 22
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Photoelectron generation
Image blooming
Optical overload
Charge-coupled device (CCD) images
Time delay and integration (TDI)
Target recognition
Target detection
Low light level (LLL)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Low-light-level television (LLLTV) imagers have an attendant susceptibility to saturation. Because of optical overload when intense sources are encountered in LLL ambients, certain pixels will saturate and spill over into adjacent pixels to cause a spreading or blooming situation. A technique is presented to classify and quantitatively characterize the contribution to blooming attributable to ships' lights at sea under very low light levels. The type of imager considered is a CCD (charge-coupled device) operating in the TDI (time delay and integration) mode used to enhance signal-to-noise and sensitivity characteristics. Also presented is a means to determine the obscuration which results from blooming when an attempt is made to recognize ships with lights at sea. Finally, obscuration projections → next page

(continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. Continued.

are superimposed over typical ships' silhouettes to determine to what extent the recognition has been impaired. Conclusions are given concerning the level of blooming control required to meet the detection and recognition requirements in the LOPATCH (Low-Light-Level Panoramic TDI-CCD Imaging System).

PROBLEM

The Navy is interested in passive detection and recognition of ships at sea under very low ambient light levels. This task involves the use of integrating-type sensors with very strong sensitivities. Unfortunately, such sensors are susceptible to optical overload and image blooming in the presence of bright sources. The LOPATCH program employs such a sensor. It is a low-light-level, panoramic, time-delay-and-integration, CCD imager. It is the purpose of this report to characterize the extent of image blooming attributable to ships' lights under very low ambient light levels for the LOPATCH sensor and to recommend a blooming control procedure which will minimize the sensitivity loss.

RESULTS

1. Equations were derived which relate the number of received photoelectrons at the sensor to the system parameters for a low-light-level, panoramic, time-delay-and-integration CCD imager (LOPATCH). This was done for target ranges up to 4 nautical miles and meteorological visibilities from 4 to 8 nautical miles. Both detection and recognition modes of operation were considered.

2. At ranges less than 1 nautical mile in the recognition mode of operation, photoelectron generation can cause vertical (line-to-line) as well as horizontal (pixel-to-pixel) spillover. This will cause multiple line vertical obscuration.

3. Horizontal obscuration projections were plotted versus target range for each mode of operation and these projections were superimposed over the profile of a KNOX-class fleet escort ship (DE 1052).

4. From these superimpositions, considering a broadside aspect, it does not appear that the recognition function will be hindered by navigation lights on ships at distances greater than 1 nautical mile.

5. From aspect angles other than broadside, fewer navigation lights will be within the field of view. Although this means less obscuration from blooming, the recognition function will be more difficult than from broadside because of the smaller profile.

6. The detection function is not hindered in any way by ships' navigation lights.

RECOMMENDATIONS

1. The recognition of KNOX-class fleet escorts by their navigation lights should not be attempted. This procedure is considered unfeasible because placement specifications, as cited in the report, are not strict and because the range to the target may not be known.

2. Column-to-column antiblooming should be implemented to inhibit vertical obscuration of ship superstructures because of blooming from ships' navigation lights.

3. The recommended TDI-CCD antiblooming structure published by the Naval Air Development Center (as NADC Technical Memorandum 30113) will accomplish much of the antiblooming required for the ships' lights problem. However, there may be no requirement for elemental antiblooming (pixel-to-pixel) whatsoever, since the recognition function does not appear to be hampered by blooming from ships' lights. In this case, the recommended antiblooming drains which extend over a fraction of the array in the TDI direction would not be necessary.

CCD BLOOMING FROM SHIPS' NAVIGATION LIGHTS

INTRODUCTION

Charge-Coupled Devices (CCDs) are presently being considered for many applications in which space availability and low-light-level sensitivity are problem areas. The submarine periscope is certainly such an application. The Navy recognizes the shortcomings of present optical periscopes and is aware of the increased performance capabilities of electro-optical imaging systems for such applications. Accordingly, the navy is presently funding a program to develop a low-light-level, panoramic, TDI (time delay and integration), CCD imaging system called LOPATCH. The program objectives are to develop the technology required for the introduction of CCD imagers into future periscopes and to demonstrate the effectiveness of a TDI-mode CCD for day and night use from such a platform. The imaging system will have a rapid-scan (search-the-horizon) capability and both wide and narrow fields of view, and will be used to recognize as well as detect surface ships at a range of 4 nautical miles under ambient light levels ranging from 5×10^{-5} to 10^4 footcandles (reference 1).

The austere low-light-level recognition requirement at 5×10^{-5} footcandles has an attendant susceptibility to sensor saturation because of optical overload. Ocean glitter and ships' lights present the largest threat in this regard. Various techniques to control this saturation problem must be considered and incorporated into the design and fabrication of the TDI CCD array. At present, the array is configured with 1024 columns, with 128 delayed integrations per column. Any of these detector sites is capable of being overloaded optically with the result of spillover of photoelectrons in both the column and row directions. A means to control this "blooming" phenomenon must be devised and recommended. The use of antiblooming busses to drain off excess signal will, of course, result in decrease in photosensitive area on the CCD array and cause reduced sensitivity. Before a recommendation can be made, a better understanding of the magnitude of the blooming resulting from ocean glitter and ships' lights is required.

The purpose of this report is to classify and characterize quantitatively the contribution to the blooming problem attributable to ships' lights under very low ambient light levels. This will be done first for the detection mode of operation and then for the recognition mode, using the respective LOPATCH system parameters for each.

REQUIRED LIGHTS AND VISIBILITY

For the purpose of specifying lighting requirements, ships are divided into three categories: those greater than 50 metres in length, those less than 12 metres in length, and those in between (reference 2). For the purpose of this report, only vessels 12 metres or more in length will be considered as they are most representative of surveillance targets for LOPATCH.

---

1. Fairchild Camera & Instrument Corp. Proposal Ed-CX-1134, Low Light Level Panoramic TDI CCD Imaging System (TOPATCH), 18 April 1977.

2. US Coast Guard Publication CG-169, Navigation Rules, International – Inland, 1 May 1977.

Special attention will be paid to lighting employed on KNOX-class fleet escort ships in a later section as these are the specific targets of interest for LOPATCH.

The US Coast Guard defines six types of night-time navigation lights for vessels more than 12 metres in length.[2] The definitions given below are illustrated in figure 1, which has been simplified by the omission of anchor, minesweeping, and towing lights on typical naval vessels.[3] Such lights are used only under very specific operational conditions, which will not be considered in this report.

1. Masthead Light.

A white light placed over the fore-and-aft centerline of the vessel showing an unbroken light over an arc of the horizon of 225° and so fixed as to show the light from right ahead to 22.5° abaft the beam on either side of the vessel. In general, the masthead light on a power-driven vessel of 12 metres or more in length shall be placed at a height above the uppermost continuous deck of not less than 6 metres, but need not be placed at a height of more than 12 metres above this deck. When two masthead lights are carried, the after one shall be at least 4.5 metres vertically higher than the forward one. In all circumstances, the masthead light or lights shall be placed so as to be above and clear of all other lights and obstructions.

2. Sidelights.

A green light on the starboard side and a red light on the port side each showing an unbroken light over an arc of the horizon of 112.5° and so fixed as to show the light from right ahead to 22.5° abaft the beam on its respective side. The sidelights of a power-driven vessel shall be placed at a height above the uppermost continuous deck not greater than three quarters of that of the forward masthead light. They shall not be so low as to be interfered with by deck lights.

3. Sternlight.

A white light placed as nearly as practicable at the stern, showing an unbroken light over an arc of the horizon of 135° and so fixed as to show the light 67.5° from right aft on each side of the vessel.

4. Towing Light.

A yellow light having the same characteristics as the sternlight defined above.

5. All-around light.

A light showing an unbroken light over an arc of the horizon of 360°.

6. Flashing Light.

A light flashing at regular intervals at a frequency of 120 flashes or more per minute.

When two masthead lights are prescribed for a power-driven vessel, the horizontal distance between them shall not be less than one half the length of the vessel but need not be more than 100 metres. The forward light shall be placed not more than one quarter of the length of the vessel from the stem.

---

3. US Naval Sea Systems Command publication 0964LP-000-2000, Lighting on Naval Ships, 15 July 1944.

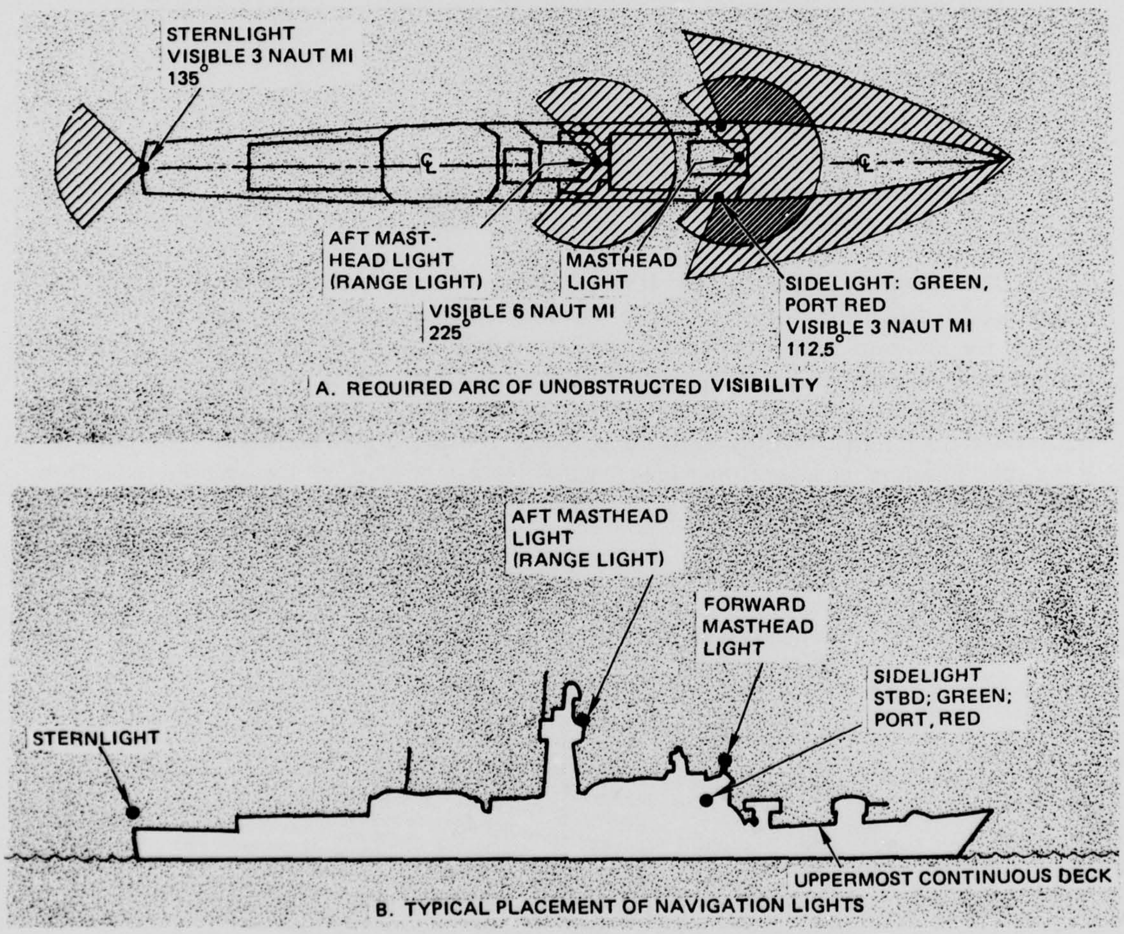


Figure 1A-B. Required visibility and placement of navigation lights (vessels larger than 50 metres).

On a vessel of 20 metres or more in length, the sidelights shall not be placed in front of the forward masthead light. They shall be placed at or near the side of the vessel.

The lights described above must have an intensity so as to be visible at the minimum ranges indicated in table 1.

Table 1. Minimum Visibility Ranges for Navigation Lights.

Type of Light	Vessel Size 50 metres or more nautical miles	 20 to 50 metres nautical miles
Masthead light	6	5
Sidelight	3	2
Sternlight	3	2
Towing light	3	2
White, green, red or yellow all-around light	3	2

The minimum luminous intensities of lights are also prescribed by the US Coast Guard (reference 2). Intensities for ranges up to 6 nautical miles are given in table 2. Here R represents the luminous range or range of visibility of light in nautical miles, and B represents the luminous intensity of lights in candelas (lumen/steradian). Although this table is generated from an equation into which the human eye response and an approximated atmospheric transmissivity of 0.8 (13-nautical-mile meteorological visibility) are considered, the value of B is a valid intensity measure from which calculations can be made concerning photoelectron generation in the CCD array.

Table 2. Intensity of Lights Versus Range.

Luminous Range, R (nautical miles)	Luminous Intensity, B (candelas)
1	0.9
2	4.3
3	12.0
4	27.0
5	52.0
6	94.0

PHOTOELECTRON GENERATION VERSUS RANGE AND VISIBILITY

The number of photoelectrons collected from a point source at range R in a CCD potential well can be calculated from the equation (reference 4 and 5).

$$N = \frac{S\Omega t}{e} B \exp\left[-\alpha_V R\right] \qquad (1)$$

where

N = number of photoelectrons

S = silicon response (amperes/lumen)

B = luminous intensity of source (lumen/steradian)

t = integration time (seconds)

e = charge of an electron (coulombs)

R = range from source to sensor

α_V = average extinction coefficient for visible spectrum

Ω = solid angle subtended by entrance aperture at range of R (steradians)

$$\left(\sigma\Omega = \frac{\text{area of aperture, A}}{(\text{range, R})^2}\right) .$$

For the case of navigation lights on ships at detection as well as recognition ranges up to 4 nautical miles, we can consider the lights as point sources with the minimum luminous intensities as specified in table 2 against a night-time, no-moon sky with effective color temperature of 2854° K. From table 3, the LOPATCH imaging system parameters, the aperture area, A, can be found from

$$A = \frac{\pi}{4}\left(\frac{f}{F_{\#}}\right)^2 \qquad (2)$$

$$A = 1.00 \times 10^{-3}\ m^2 \ .$$

Using this result and converting units of length, the solid angle subtended by the aperture is

$$\Omega = \frac{2.921 \times 10^{-10}}{R^2} \qquad (3)$$

4. Campana, SD, Charge Coupled Device for Low Light Level Imaging, CCD Applications Conference, September 1973.

5. Sears, FW, Optics, chapter 13, Addison-Wesley, 1958.

Table 3. LOPATCH Imaging System Parameters

OPTICS	
1. Recognition Mode	
Focal length, f	200mm
$F_{\#}$	1.6
2. Detection Mode	
Focal length, f	50mm
$F_{\#}$	1.4
SCAN TIME	360° in 10 seconds, 36°/s
TDI-CCD	
Pitch	20μm V and H
Integration time (effective)	.81 ms
Response, 2854°K source	4.4 mA/lumen
Full well capacity	10^6 electrons
TDI extent	128 elements per column

where R is in nautical miles. The average extinction coefficient for the visible range (0.38μm through 0.72μm) depends as follows on the meteorological visibility (reference 6)

$$\alpha_V = \frac{3.912}{V} \tag{4}$$

where the units of α_V are determined by the units of V.

Again using table 3, we see that

$$\frac{St}{e} = 2.28 \times 10^{15} \quad . \tag{5}$$

Now substituting results from equations 3,4, and 5 into equation 1 yields

$$N_D = 6.506 \times 10^5 \frac{B}{R^2} \exp\left[-\frac{3.912}{V} R\right] \tag{6}$$

where N_D represents the number of received photoelectrons in a potential well in the detection mode of operation. This result has been used to generate figures 2 through 5. It yields the minimum number of photoelectrons to be expected in the detection mode when the value of B is selected from table 2.

For example, assuming a night sky with no moon, a meteorological visibility of 8 nautical miles, and a target vessel greater than 50 metres in length at a range of 3 nautical miles, then

V = 8 nautical miles

R = 3 nautical miles

B = 94 candelas

N_D = 1.57 million photoelectrons

---

6. RCA Technical Series EOH-11, Electro-Optics Handbook, sections 6, 7, and 12, 1974.

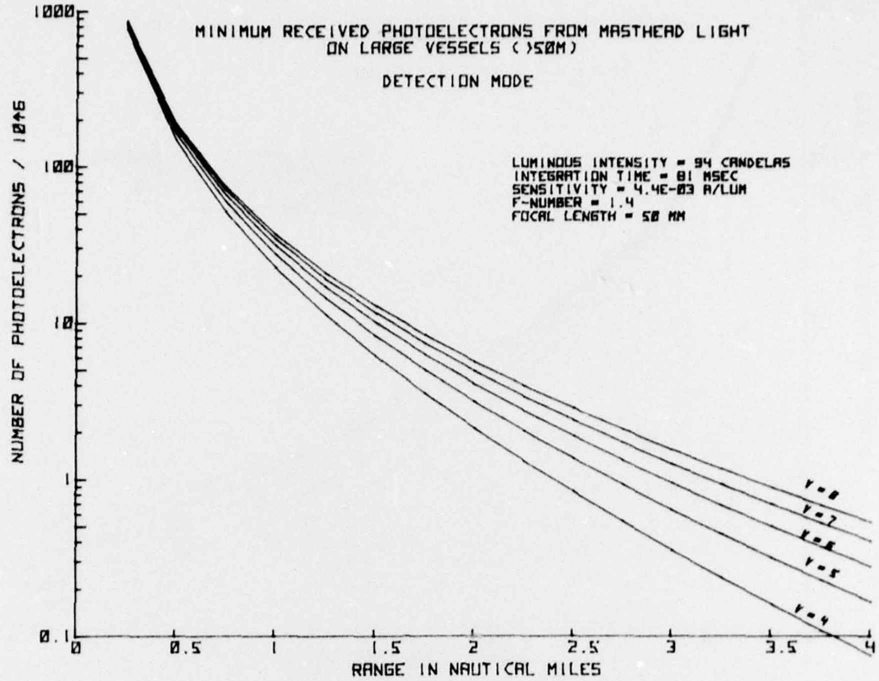


Figure 2. Photoelectrons versus range, detection mode: luminous intensity = 94 candelas.

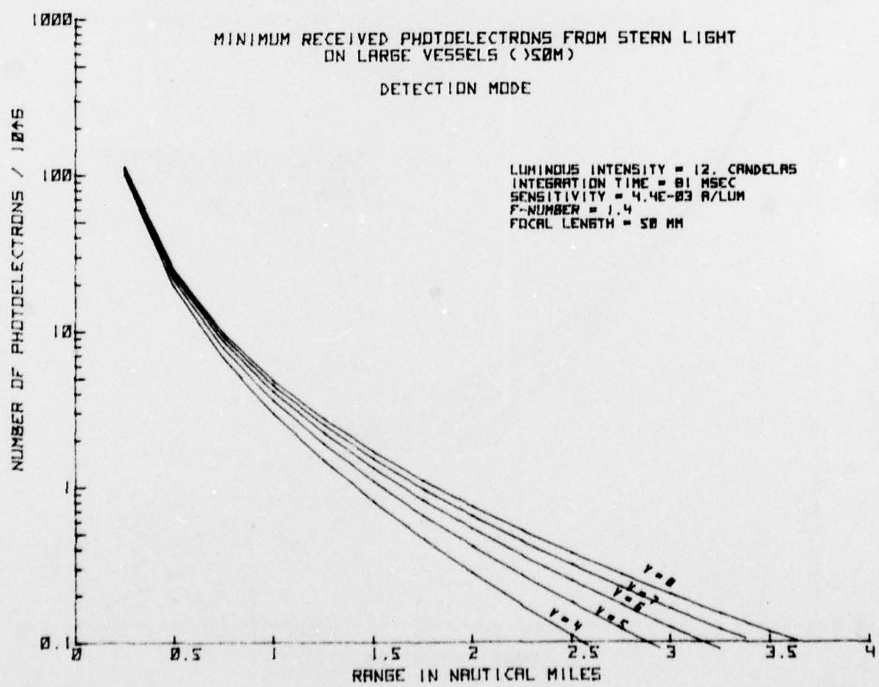


Figure 3. Photoelectrons versus range, detection mode: luminous intensity = 12 candelas.

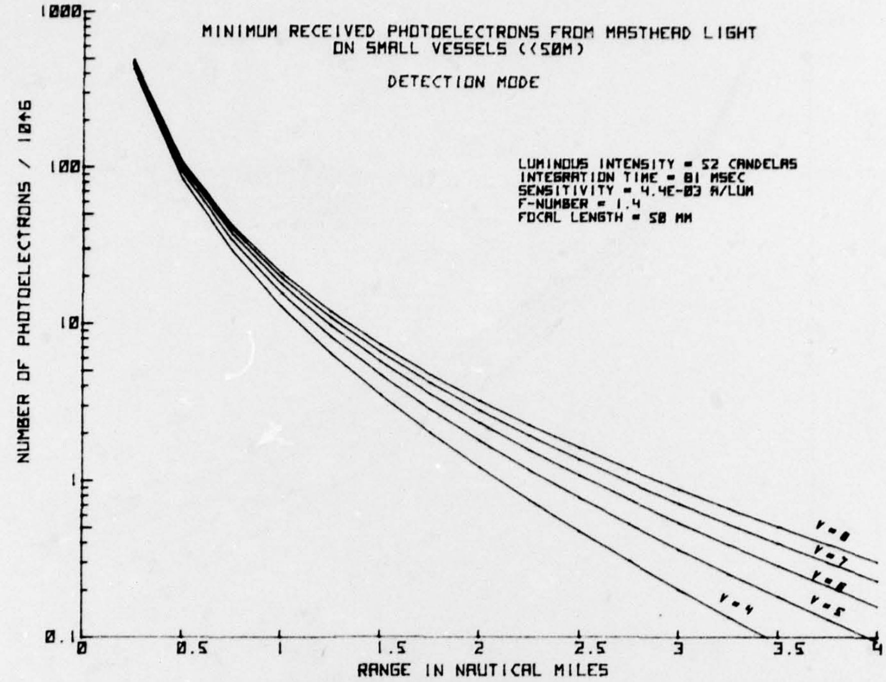


Figure 4. Photoelectrons versus range, detection mode: luminous intensity = 52 candelas.

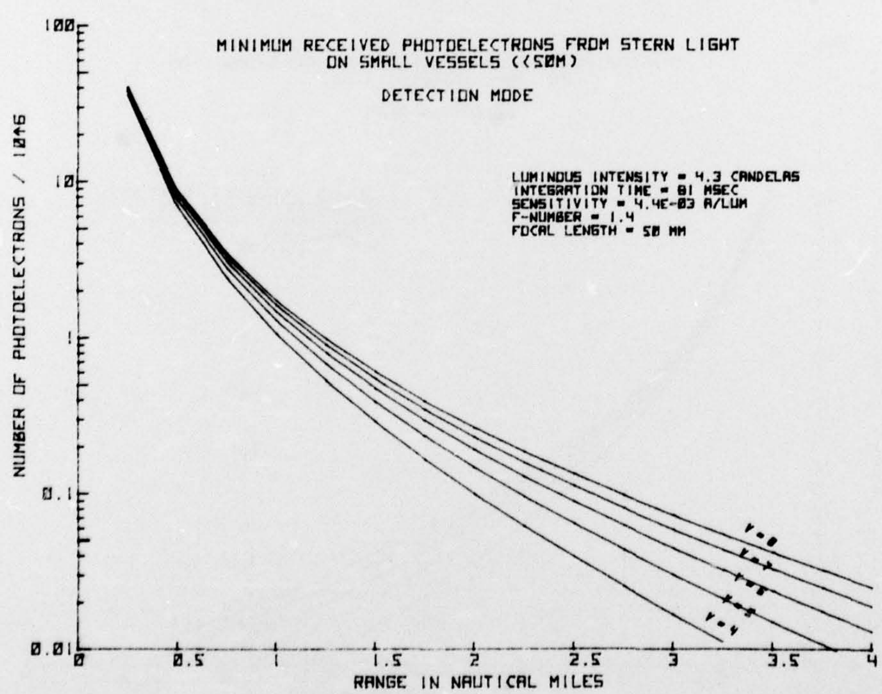


Figure 5. Photoelectrons versus range, detection mode: luminous intensity = 4.3 candelas.

This result is contained in figure 2 on the curve for $V = 8$ at a range of 3 nautical miles. Figure 2 represents a family of curves pertinent to the detection mode and derived from varying meteorological visibility ($4 \leq V \leq 8$) and range ($0.5 \leq R \leq 4$) for a constant B of 94 candelas in equation 6. This is the minimum required luminous intensity for a masthead light on a vessel greater than 50 metres in length.

Figure 3 is a set of curves for the detection mode derived from equation 6 assuming $B = 12$, which is the minimum luminous intensity required for stern, side, towing or all-around lights on a vessel greater than 50 metres in length.

Figures 4 and 5 are corresponding detection mode curves for navigation lights for ships greater than 12 metres in length, but less than 50. $B = 52$ candelas and 4.3 candelas, respectively, for figures 4 and 5.

To obtain an expression corresponding to equation 6 for the recognition mode, with the smaller FOV one need only consider the change in optics assuming as is presently planned for LOPATCH, the detection scan rate is decreased appropriately to yield the same integration time. Specifically, the entrance aperture area for the recognition mode optics is

$$\frac{\pi}{4}\left(\frac{f}{F_{\#}}\right)^2 = \frac{\pi}{4}\left(\frac{200\text{mm}}{1.6}\right)^2$$

which is 12.25 times larger than the area for the detection mode. This relates proportionally to N, yielding

$$N_R = 12.25\ N_D \tag{7}$$

or

$$N_R = 7.97 \times 10^6\ \frac{B}{R^2}\ \exp\left[-\frac{3.912}{V}\ R\right] \tag{8}$$

where N_R represents the number of received photoelectrons in a potential well in the LOPATCH CCD array in the recognition mode of operation.

This result has been used to generate the curves in figures 6 through 9. It yields the minimum number of photoelectrons to be expected in the recognition mode when the value of B is selected from table 2.

For example, assuming a night sky with no moon, a visibility of 8 nautical miles, and a masthead light on a target greater than 50 metres at a range of 3 nautical miles, then

V = 8 nautical miles

R = 3 nautical miles

B = 94 candelas

N_R = 19.5 million photoelectrons.

The result is contained in figure 6 on the curve for $V = 8$. Figure 6 represents a family of curves pertinent to the recognition mode and derived from varying visibility and range for a constant B of 94 candelas in equation 8. Again, this is the minimum required B for a masthead light on a vessel greater than 50 metres in length.

Figures 7, 8, and 9 present N_R versus R for ships' lighting situations analogous to figures 3, 4, and 5 except that the results pertain to the recognition mode of operation.

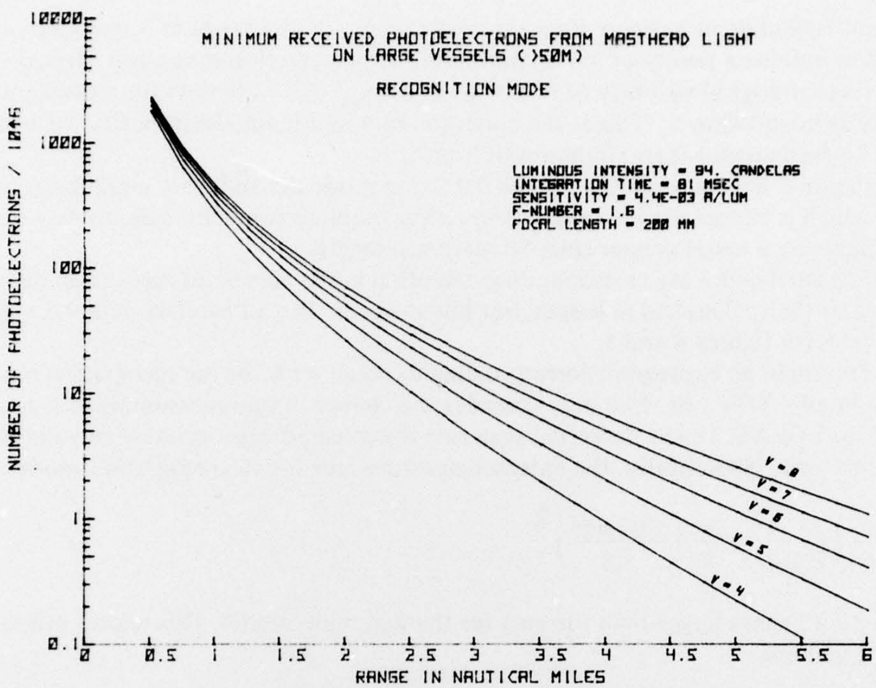


Figure 6. Photoelectrons versus range, recognition mode: luminous intensity = 94 candelas.

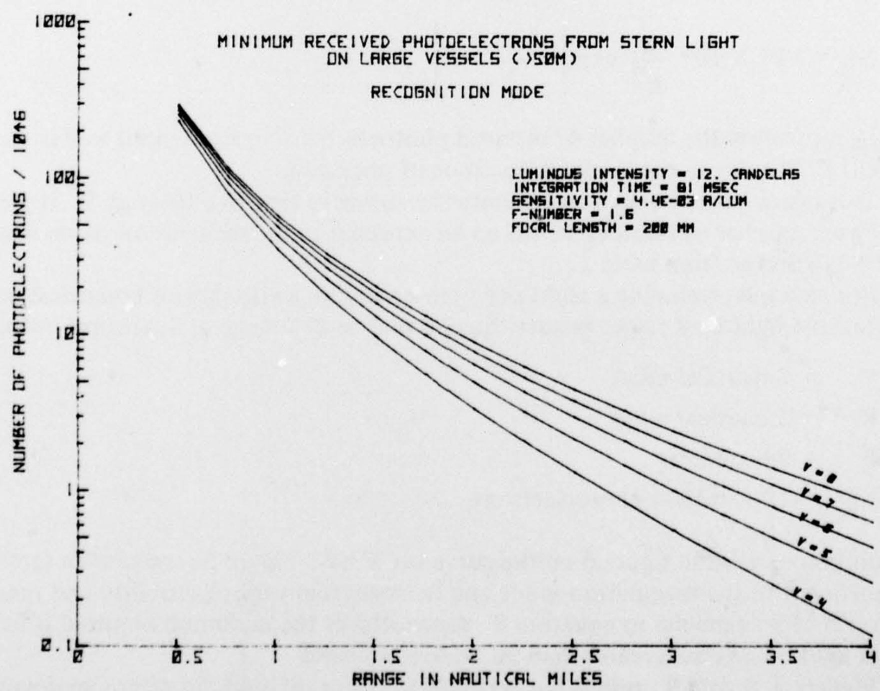


Figure 7. Photoelectrons versus range, recognition mode: luminous intensity = 12 candelas.

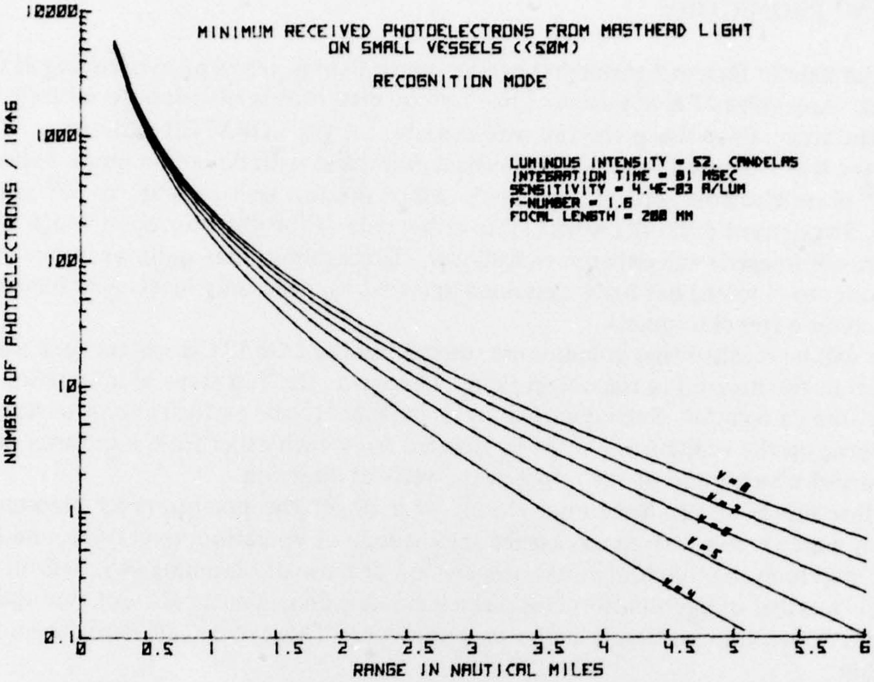


Figure 8. Photoelectrons versus range, recognition mode: luminous intensity = 52 candelas.

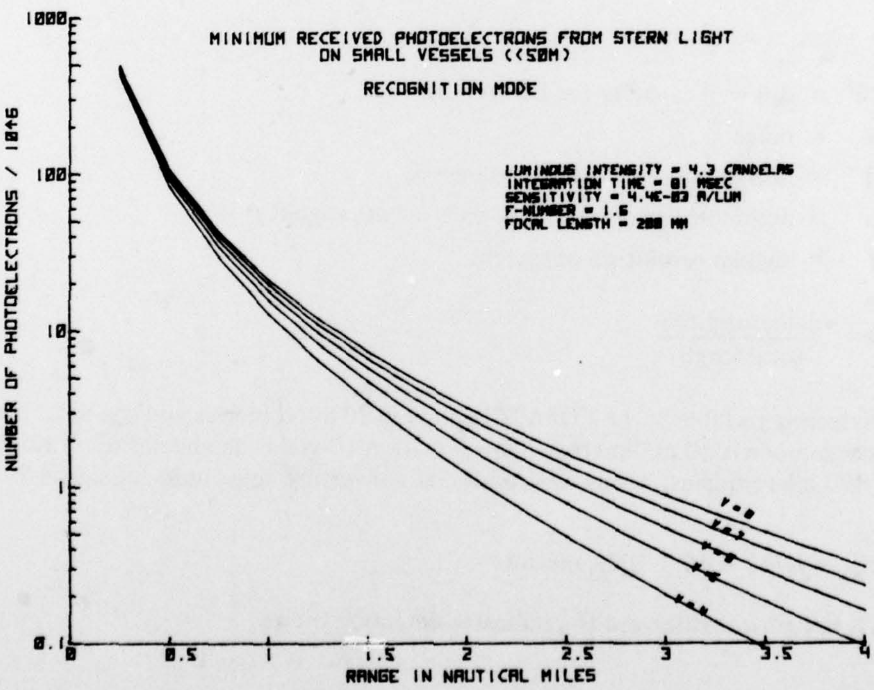


Figure 9. Photoelectrons versus range, recognition mode: luminous intensity = 4.3 candelas.

BLOOMING PROJECTION

The data in figures 2 through 9 can be interpreted in terms of overloading at the pixel level. Any value of N in excess of one million electrons is sufficient to saturate a point in the array, since this is the full well capacity for the LOPATCH CCD array. Thus in figure 2, for R = 1 nautical mile, V = 8 nautical miles, and with detection mode optics, 38×10^6 photoelectrons will be generated. Since the full well capacity is 10^6 photoelectrons, 38 adjacent potential wells (19 to either side of the detector upon which the point source is imaged) will experience spillover. This assumes that spillover in one direction (column-to-column) has been contained and that we need only investigate blooming within a column (pixel-to-pixel).

It will be recalled that columns are oriented in the LOPATCH system such that they are parallel to the horizon in the object field. Therefore, the 128 steps of integration occur within or along a column. Such columns are orthogonal to the vertical extent of targets which appear on the horizon and must be isolated from each other from a spillover standpoint to arrest obscuration of the target in the vertical direction.

How much of the horizontal extent of a target the pixel-to-pixel blooming obscures is a matter which varies with range, aspect angle, mode of operation, target size, and profile. As a first step to evaluating horizontal obscuration because of blooming, it is helpful to project the number of overloaded pixels, which is range-dependent, back out through the optics onto representative targets at the various ranges. This can be calculated using the relationship

$$H = \frac{\theta NR}{10^6} \tag{9}$$

where

10^6 = full well capacity for LOPATCH

R = range

H = horizontal obscuration at range R

N = number of photoelectrons received at range R

θ = angular resolution of system

$$\theta = \frac{\text{detector pitch}}{\text{focal length}} \ . \tag{10}$$

Referring to table 3, the LOPATCH pitch is 20 micrometres and the focal length in the detection mode is 50 millimetres. Now equation 10 yields an angular resolution, θ, equal to 400 microradians. Using this result and converting range units, equation 9 can be written

$$H_D = 0.741 \times 10^{-6}\ RN_D \text{ metres} \tag{11}$$

where R is in nautical miles and H_D indicates detection mode.

For the recognition mode, equation 9 must reflect the fact that N and θ will be different than they were in the detection mode. It will be recalled that

$$N_R = 12.25\, N_D \quad .$$

Realizing that the focal length in the recognition mode optics is four times that of the detection mode, one can derive the equation

$$H_R = 3.0625\, H_D \qquad (12)$$

in which H_R, horizontal obscuration for the recognition mode, can be found if H_D is known.

Equations 11 and 12 have been used to generate the horizontal obscuration, H, as a function of range, R, in figures 10 and 11. The value of H is actually an extent, in metres, over which image data will be obscured because of blooming from ships' lights. For example given a large vessel with masthead light on at a range of 2 nautical miles in the recognition mode, 26 metres of obscuration is to be expected. Depending on the placement of the masthead light, this could block out 13 metres of superstructure on either side of the masthead light because of overload and blooming when the image is displayed. Figure 10 considers the lights encountered on large vessels and predicts the extent of obscuration possible from both the detection mode (H_D) and recognition mode (H_R) of operation for various ranges. Figure 11 considers small vessels in an analogous manner. The situations noted with the asterisk (*) indicate that more than 128 million photoelectrons will be received.

The convenience of presenting obscuration as in figures 10 and 11 is apparent when one considers that it is independent of the display and target aspect angle and size.

SPECIAL CASE: KNOX-CLASS ESCORT SHIPS

The specific target for recognition and detection with the LOPATCH system is the KNOX-class escort (DE 1052). It is the largest of the DE types, displacing 4100 tons and having a length of 133.5 metres (references 7 and 8). Figure 12 shows such a ship in broadside profile as it would appear under full load in the water. Also shown on this profile is the placement of the 2 masthead lights, the starboard sidelight, and the sternlight. The approximate scale is 1:750.

One can superimpose the expected horizontal projections from figures 10 and 11 upon such a profile to determine the approximate amount of obscuration because of blooming that the ship's superstructure will experience when displayed. This is the intention in figures 13 and 14. No attempt was made to approximate the ship's image size on the display in these figures. The obscurations were merely superimposed onto the profiles with the same scale factor mentioned earlier.

In figure 13, the assumed range is 1 nautical mile for both detection and recognition modes. Further assumptions include: symmetrical blooming, column-to-column antiblooming, full integration, and light intensities as specified in table 2. It should be noted that the vertical extent of each projection in the recognition mode is four times smaller than that in

7. Moore, CAPT JE, compiler, Jane's Fighting Ships, 1975-76 edition, p 13 and 466.
8. Van Orden, CAPT MD, The Book of United States Navy Ships, p 70-74, Dodd, Mead, 1969.

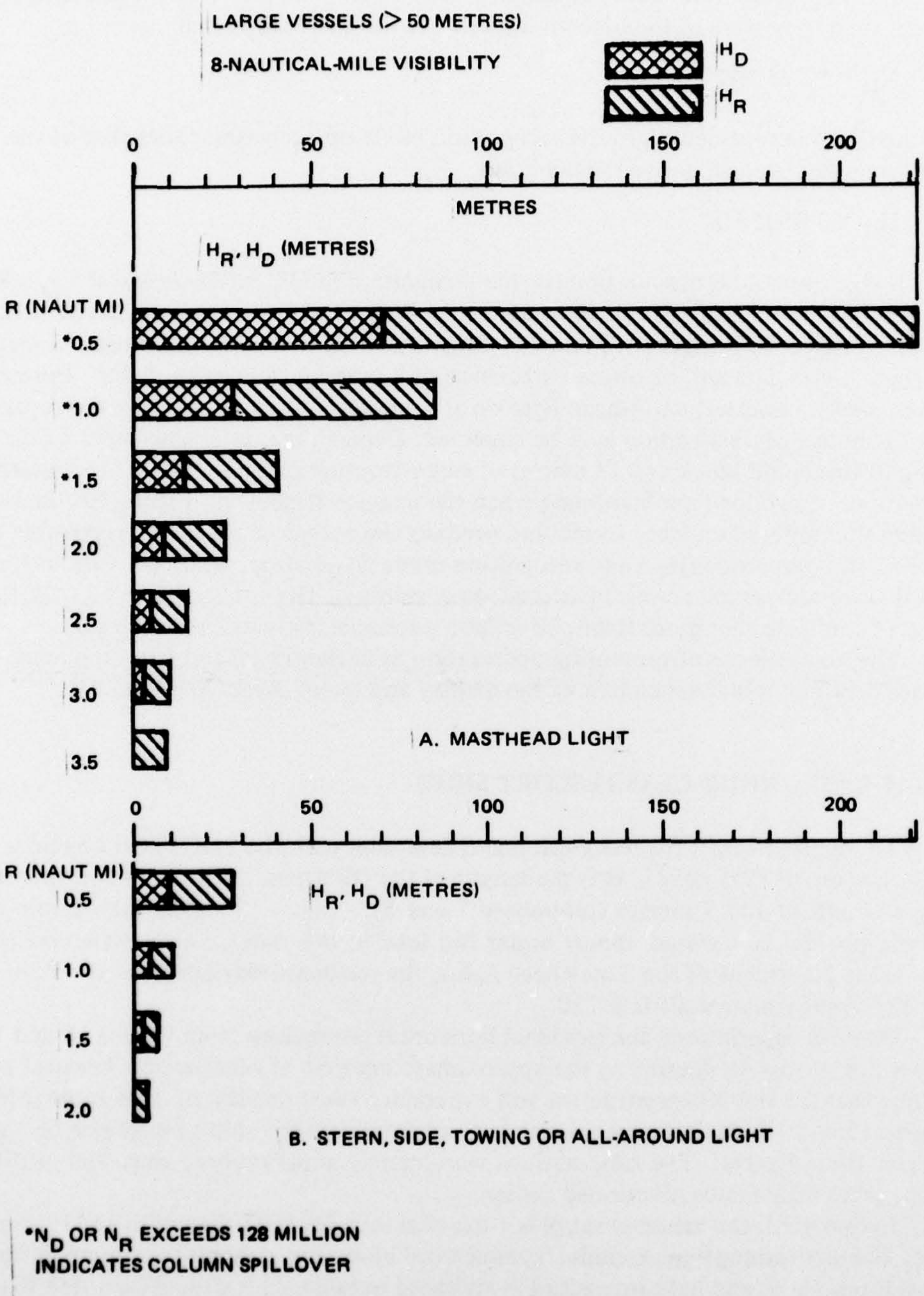


Figure 10. Horizontal obscuration projection, H, versus R.

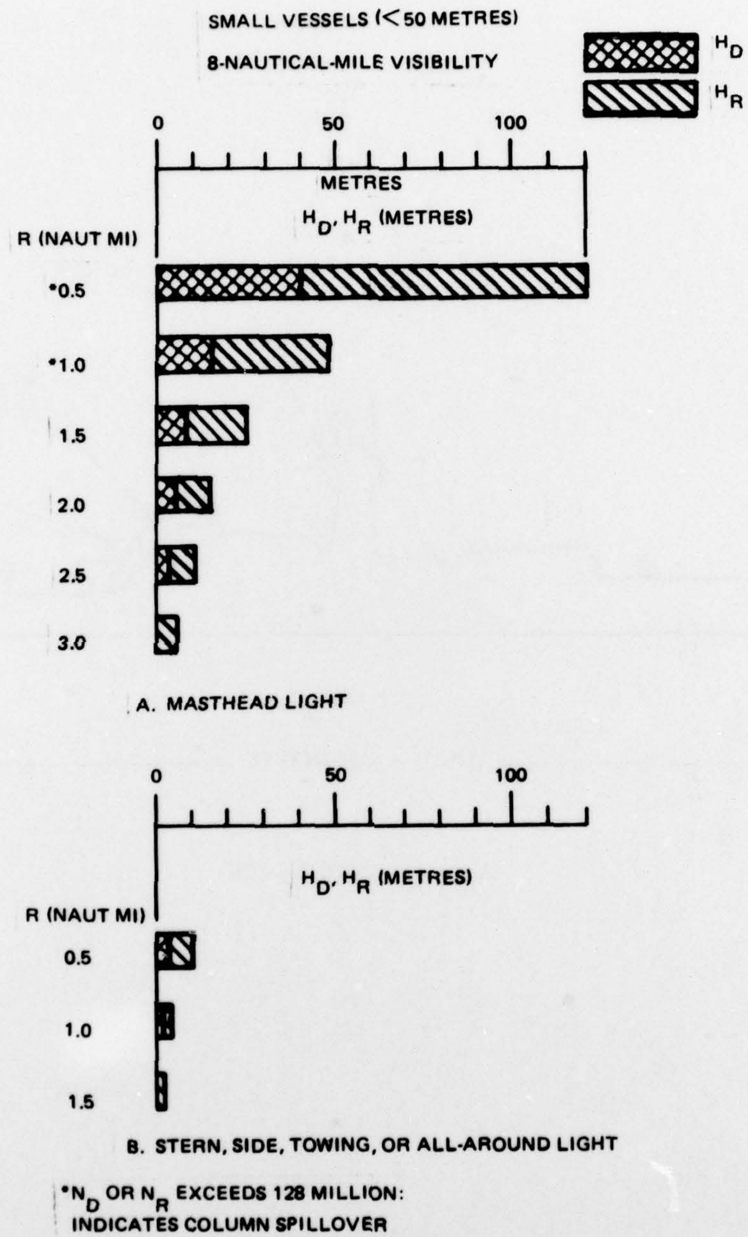


Figure 11. Horizontal obscuration projection, H, versus R.

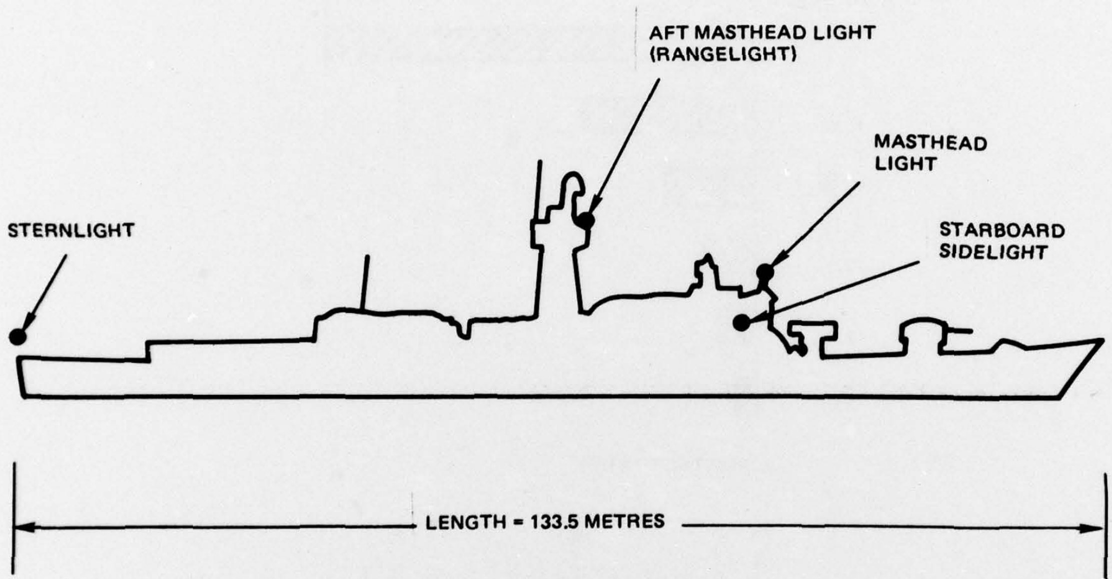
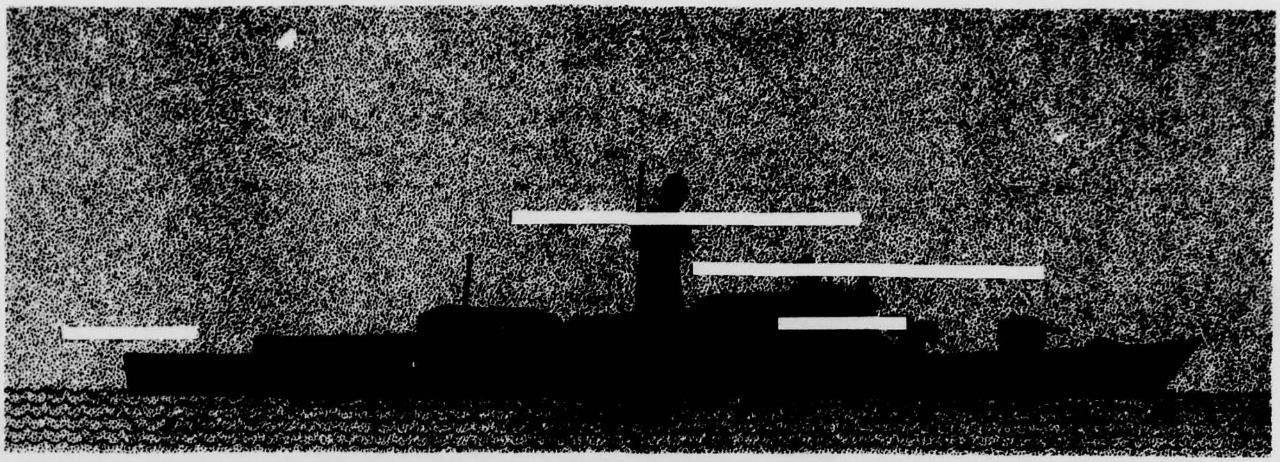
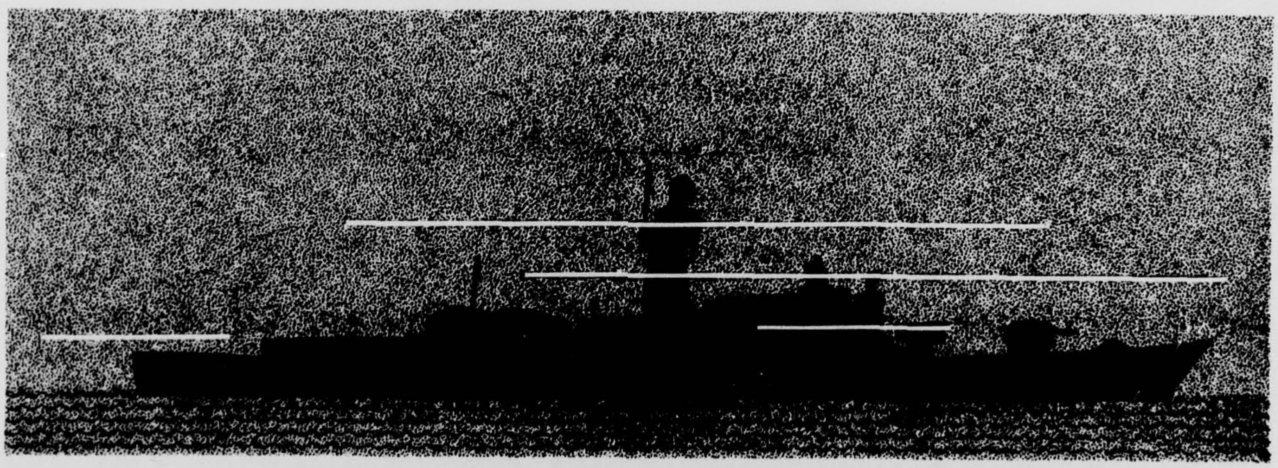


Figure 12. DE 1052 profile.

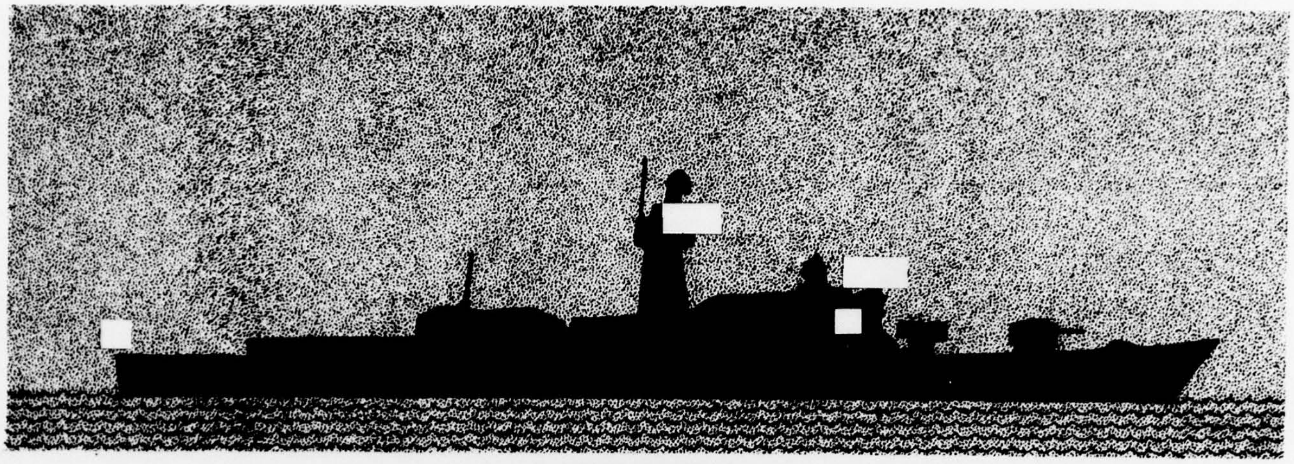


A. DETECTION MODE

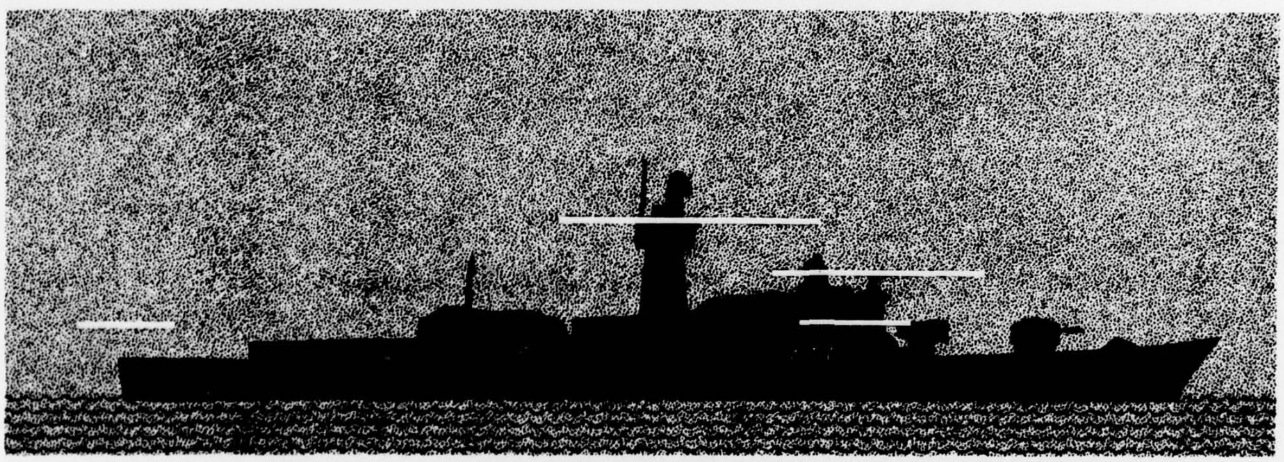


B. RECOGNITION MODE

Figure 13. DE 1052 broadside at 1 nautical mile; vessel length = 133.5 metres.
Blooming obscuration extent is shown.



A. DETECTION MODE



B. RECOGNITION MODE

Figure 14. DE 1052 broadside at 2 nautical miles; vessel length = 133.5 metres.
Blooming obscuration extent is shown.

the detection mode. This is because of the smaller pixel projection through the larger recognition optics. In figure 14, the assumed range is 2 nautical miles. The vertical extent of the blooming projections is twice as great in each case as those in figure 13. This is because of the linear increase in pixel projection with range. However, the horizontal extent of the projections in figure 14 is less than those in figure 13 in each case. This is so because the attenuation effect with range evident in equations 6 and 8 is stronger than the increased pixel projection effect.

Of the cases depicted in figures 13 and 14, probably 13.B is the most deleterious from the standpoint of recognizing the KNOX profile by its superstructure. Subjectively, though, it still appears to be highly recognizable. In fact, at ranges greater than 1 nautical mile, it does not appear that the recognition task will be significantly hindered because of blooming from ships' navigation lights.

CONCLUSIONS

1. The detection function is not hindered in any way by ships' navigation lights.

2. From a broadside aspect, it does not appear that the recognition function will be hindered by navigation lights on ships at distances greater than 1 nautical mile.

3. Column-to-column antiblooming is necessary to inhibit vertical obscuration of ship superstructure because of blooming from ships' navigation lights. At distances of less than 1 nautical mile in the recognition mode of operation, photoelectron generation can exceed 128 million. Without column-to-column antiblooming, this would cause multiple-column vertical obscuration.

4. From aspect angles other than broadside, fewer navigation lights will be within the field of view. Although this means less obscuration from blooming, the recognition function will be more difficult than from broadside because of the smaller profile.

5. Recognition of KNOX-class escort ships by the placement of their navigation lights does not seem feasible since placement specifications, as cited within, are not strict and the range to the target may not be known.

6. The recommended TDI-CCD antiblooming structure, which appears in reference 9, will accomplish much of the antiblooming required for the ships' lights problem. However, as discussed above, there may be no requirement for elemental antiblooming whatsoever since the recognition function does not appear to be hampered by blooming from ships' lights. In this case, the antiblooming drains which extend over a fraction of the array in the TDI direction would not be necessary.

---

9. Naval Air Development Center Technical Memorandum NADC 30113, Consideration of Blooming Control Structures for TDI-CCD Images, by SD Campana, 22 February 1977.

REFERENCES

1. Fairchild Camera & Instrument Corp. Proposal ED-CX-1134, Low Light Level Panoramic TDI-CCD Imaging System (TOPATCH), 18 April 1977.

2. US Coast Guard publication CG-169, Navigation Rules, International – Inland, 1 May 1977.

3. US Naval Sea Systems Command publication 0964LP-000-2000, Lighting on Naval Ships, 15 July 1944.

4. Campana, SD, Charge Coupled Device for Low Light Level Imaging, CCD Applications Conference, September 1973.

5. Sears, FW, Optics, chapter 13, Addison-Wesley, 1958.

6. RCA Technical Series EOH-11, Electro-Optics Handbook, sections 6, 7, and 12, 1974.

7. Moore, CAPT JE, compiler, Jane's Fighting Ships, 1975-76 edition, p 13 and 466.

8. Van Orden, CAPT MD, The Book of United States Navy Ships, p 70–74, Dodd, Mead, 1969.

9. Naval Air Development Center Technical Memorandum NADC 30113, Consideration of Blooming Control Structures for TDI-CCD Images, by SD Campana, 22 February 1977.